After the Analysis: Establishing the Probative Value of Trace Evidence

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Abstract

A variety of analytical tools are available to the trace evidence examiner: Elemental analysis of minute samples of material, chemical identification and spectral analysis of coloring agents, and chemical identification of polymeric materials. The analyst can gather more data about less material than ever before possible. But what does this data mean? How does the analyst establish the significance the analysis, or any combination of analyses, and how is that information presented in a way that a jury can assess the probative value of the evidence? How can unlikely, but plausible, alternative hypotheses that explain the evidence be tested. Who has the responsibility of establishing the probative value of such evidence, and determining whether the value of such evidence, in general or in any particular case, is appropriately used in a trial? The first question the analyst must answer is whether or not any subsequent analysis performed on the evidence provides any more information than the first analysis. This question must be asked for each analysis that is conducted after the initial determination that evidence and exemplar samples could share a common origin. Once the analyses have been completed, and evidence and exemplar samples cannot be differentiated, the hypothesis that the samples share a common origin has not been eliminated. But this *inductive* hypothesis, that the evidence could be from an alleged source which has the same properties as the evidence, is not quite the problem posed to the forensic scientist. The forensic scientist is actually interested in the *abductive (*Peirce, p. 8) hypothesis: The evidence is from the particular source that is relevant to the case at hand. The inductive process is equivalent to the Kirkian (Kirk, p. 10) process of identification, and the abductive process is equivalent to the Kirkian individualization. If this problem is not enough, the forensic scientist must also deal with another problem - the “innocent explanation” for the apparently incriminating evidence. Trace evidence materials are not unique in the same way that fingerprints or DNA sequences are associated with a single individual source. Most trace evidence materials are mass produced as raw materials, incorporated into large numbers of manufactured products which are, in turn, used to produce diverse end-use or consumer products. When the analysis has been completed, is a statement in a report that says that the “evidence sample and the exemplar material are analytically indistinguishable and therefore could share a common origin” all that one can expect from the forensic scientist? Should the forensic scientist be expected to say more? What is it necessary to do to say more?

INTRODUCTION

Credibility Problem

In a recent discussion on the "forens" internet discussion group (Forens) comments were made about the "non-scientific" forensic disciplines, as contrasted with the "scientific" ones. The "scientific" one is, of course, DNA analysis. The "non-scientific" disciplines are the usual candidates, particularly trace evidence and firearms identification. DNA typing is the "new model" for scientific forensic identification. (Saks & Koehler).

Certainly, as in all fields of human endeavor (even including DNA analysis) mistakes are made. Certainly, as in all human endeavors, there are people who are dishonest. But also, there is a certain lack of understanding of criminalistics, even among those who are accepted, by a process of peer review, as expert critics. In a recent article two critics (Saks and Koehler) allege that "traditional forensic scientists seek to link crime scene evidence to a single person or object . . . by leaning on the assumption of discernible uniqueness." (Saks & Koehler) The fact that Saks and Koehler believe, apparently, that "discernible uniqueness" is a "central assumption" of forensic science may illustrate the fact that forensic scientists themselves either do not understand the fundamental principles -- Kuhn's "paradigm" (Kuhn, p. 43) -- of criminalistics. Or, perhaps, we simply have not done a very effective job in communicating the information to other scientists and, especially, our would-be critics.

Scientific Investigation

We need to consider whether our job as forensic scientists is to do a technical analysis of material that is collected as "evidence" in a case, or whether our job is to conduct a scientific investigation that will help shed light on what happened in the incident that is under investigation.

As scientists we must believe that we have something to add to the system that investigates incidents which may be the subject of some legal inquiry. Indeed, that is the reason for this conference. If we wanted simply to do analyses we would not be here today - we would be at an analytical conference where we could learn about all the new techniques that are available, see the new instruments that are touted for their ability to get more information, with smaller samples, at lower cost, and more quickly than the instrument we paid $150,000 for last year. But we are here because we want to discuss how the work we do might be more effectively used in the resolution of problems, or the solution of mysteries, that are the subject of legal inquiries. What can we do to accomplish that goal?

Understand our job

The first step in the process of convincing others that we have something of value to add to the judicial system is to convince ourselves of that fact, and to understand how to develop the full value of what we do. An opinion that fibers "could have" come from the alleged source is of little value. As one analyst recently stated, "Given how much evidence they had in the case, I wasn't crucial. The prosecutors liked the idea of fibre evidence in addition to everything else. Maybe they thought then jury would like it because it was more CSI-esque." (Tobin)

There must be some better way to express our conclusions than "it could have come from." If nothing else, an experienced trace evidence analyst should have some sense of how common it is to find "matching" fibers on two items that have not been in contact. The value of experience should not be underestimated or ignored. Even if the fiber evidence may not be too important in linking the suspect to the crime scene, especially given that victim's blood was found on the suspect's clothing, the trace evidence might have been useful in determining exactly what happened in the incident. Use of such evidence does not involve the individualization of the evidence; it involves only the consideration and testing of alternate hypotheses.

SOME DEFINITIONS

In order to conduct a scientific investigation, we must understand a few principles. These may seem obvious and irrefutable but are nevertheless important to explicitly state. Then we must consider the basic processes that we use to take advantage of the principles to arrive at the answers we hope to obtain. The principles and processes, together with the limitations imposed by the nature of the job, define the paradigm under which forensic science is conducted.

Principles

Principles are things that we believe but cannot, or do not, prove. These are called, in mathematics, “axioms.” In other branches of science these principles are often called “laws” (the Laws of Motion, the Laws of Thermodynamics). In forensic science literature what might otherwise be called an axiom or a law is referred to as a “principle.” Not all principles applicable to forensic science have necessarily been defined, but I think there are at least three that are commonly accepted by forensic scientists. These can be stated as the:

<u>Principle of Individuality (or uniqueness)</u>

This principle can be stated as "no two objects in nature are identical." (Kirk, p.10) Since we cannot compare all physical objects with all other physical objects, this assumption cannot be directly tested. Any indirect test of this hypothesis depends on our analytical ability to determine all properties of any object. We are continually searching for techniques to determine the uniqueness of objects. This is the operation some Kuhn somewhat flippantly dismisses as the "mop up" operation (Kuhn, p. 24), even though he recognizes its importance and difficulty. It is usually easy by simple observation to determine that two objects are unique. It is not the uniqueness that is the problem we are trying to solve. Rather, it is the determination that properties that are shared by two objects suggest that they either have a common origin, were produced by the same operation, or that one object was produced by the other.

The Principle of Individuality describes why it is possible to establish links between evidence and exemplar items.

<u>Principle of Divisible Matter</u>

The principle of divisible matter has been proposed by Inman and Rudin (Inman, p. 83). I propose a somewhat different statement than their original: "Matter divides into smaller components when sufficient force is applied." This statement of the Principle of Divisible matter has at least three corollaries:

1. The process of division may produce features that are unique to the two pieces.
2. When an object is separated into pieces, some features of the one piece will be retained by the separated piece.
3. The passage of time may affect the two pieces differently

The Principle of Divisible Matter, with its corollaries, describes how the objects which become evidence are produced.

<u>Principle of Transfer (or the Locard Exchange Principle)</u> (Inman, p.93)

This principle can be stated as "when two objects come into contact, matter will be transferred from one object to the other, and from the other to the one." There are several corollaries to the Principle of Transfer:

1. When contact occurs between two objects, the transfer may be in either direction or both directions.
2. The rate and quantity of transfer depends on the properties of the materials in contact, the forces involved in the contact, and the time of such contact.
3. The persistence of transferred matter depends on the properties of the transferred matter, the properties of the recipient object, and post-transfer actions affecting the recipient and transferred objects.

The Principle of Transfer describes how items of physical evidence become displaced in space.

These three principles, at least, are utilized in a series of processes that can be referred to as "Unit Operations."

Unit operations

"Unit operation" is a term that derives from the field of chemical engineering but has been applied to such diverse fields as video game criticism and poetry. "Unit operations" can be defined as "A structure of logic used for synthesizing and analyzing processing schemes in the chemical and allied industries, in which the basic underlying concept is that all processing schemes can be composed from and decomposed into a series of individual, or unit, steps." (McGraw-Hill)

The scientific investigation conducted by criminalists, those scientists who utilize physical evidence in an investigation to determine what happened during a particular incident, involves the following unit operations:

Recognition

Recognition is the process of understanding and locating matter that may inform us abut the circumstances of an event we are considering. The process of recognition does not simply mean "perceiving", it also implies understanding. How can this piece of matter inform us about its circumstances? How did it come to be lying on the floor at the scene, or lying on my lab bench, or being injected into my GC/MS? What is the history of this item; what is its present condition; how can I preserve the item so that it will be as informative in the future as it is now; how has the item changed over time; when did those changes occur?

Preservation

This may seem like a simple operation: pick it up and put it in an appropriate container so that it will not get ruined so the lab can do whatever examination I ask for, or they can do, with this evidence. This is the equivalent of the pediatrician who sees a coughing child, who is crying, has a fever, and reddish throat and concludes that the child has a viral infection that should be left untreated - common complaints, routine systems, and simple diagnosis and treatment. But what about the unusual, unexpected, or unobserved? This is where the knowledge of the doctor comes into play. Similarly, at a crime scene, the unexpected, unusual, or unobserved may be the most important. The importance of the physician's attention to the child is the same as the importance of the criminalist's attendance at a crime scene. Of course, we do not train physicians by giving them only patients with the most obscure diseases, with tricky diagnoses, complex treatment possibilities, and uncertain outcomes. Nor will criminalists become good at evidence recognition simply by going to the most serious or most complex scenes. Going to scenes should be a routine part of the criminalist's job.

Identification

The Identification operation is no more and no less than giving something a name. There are many ways of naming things: a simple name (fiber), a common name (human head hair), a technical name(quartz), a chemical name(Sodium carbonate), a trade name (nylon), or simply a descriptive name ("a transparent, red, birefringent particle). Depending on the nature of the item, such identification of the material may be sufficient to answer the relevant question, or it may simply lead to the next unit operation.

Individualization

Individualization is the process of determining that two things have a common origin, or stated in a slightly different way, that one thing (usually the "evidence" or Q sample) was originally part of another thing (usually the exemplar or E sample). Just as identification is a process, without any necessary end point, so is individualization a process.

Reconstruction

The final unit operation of forensic science is reconstruction. In general, criminalists routinely are concerned with reconstruction: Persistence and transfer of trace evidence material, interpretation of blood spatter patterns, determination of bullet trajectories, fracture or damage to objects, or changes to the environment caused by an event. In general, the changes that result from some action in the environment of an event produce physical manifestations that can be observed, tested, measured, or documented to determine the nature of, and cause of, those changes. Reconstruction can be defined as the determination of the time sequence of events that occurred during the event being investigated.

SOME PROBLEMS

Forensic science is one of the several applied sciences which have the responsibility of reaching a conclusion and applying that conclusion to the resolution of some matter. That matter may be the diagnosis of an illness by a physician, the resolution of a manufacturing problem in a production facility, the reconstruction of an archaeological site, or the reconstruction of some recent event during which a crime may have been committed. Each of these disciplines have their own set of problems and limitations: Living patients make certain diagnostic procedures (for example, autopsies) impossible; artifacts buried underground for hundreds of thousands of years are not properly preserved; improperly manufactured widgits can be destroyed or recalled.

Forensic scientists are faced with a task that is not common in the natural sciences: We investigate a specific incident rather than a material. We can do all of the analysis we care to of a material, and generate reams of precise and accurate data, but if that work does not lead to a greater understanding of the incident, it is of no value. We also have to come up with a conclusion which will have essentially permanent consequences - at least to a few people. The "inconclusive" conclusion (besides being an oxymoron) is of no value, and is frequently misunderstood or misrepresented.

Like other of the applied sciences, criminalistics has its own set of complications: what is or is not evidence is not always immediately apparent; issues may not be well defined, or even known, at the time that collection of relevant evidence is possible; a decision has to be made based on factors other than what best serves a scientific investigation of the incident; whatever decision is made must be considered to be a final one, even though it may not be; and, there may be conflicting evidence, such as eye witnesses or motives, which will be considered in the ultimate decision that is made.

Forensic science investigation has problems which are no more or no less -- just different from -- problems in other applied science endeavors. Even though the problems may be somewhat different in various applied science disciplines, the problems can be broadly defined by two types of errors: Technical and Cognitive. (Groopman, p. 24)

Technical errors

Technical errors are such things as sample mix-ups, laboratory contamination, or failure to run certain controls or calibrations. Technical mistakes can also include unavoidable analytical errors - analytes of interest may be below limits of sensitivity of the technique, there may be unknown interferences that give misleading results in an analysis, or there may simply have been a human error in reading data. Some of these mistakes can lead to disastrous results; some are relatively benign. Many, if not most, of these mistakes can be detected by quality assurance procedures.

Cognitive errors

Cognitive errors are errors of a different sort: these are errors in thinking, in not understanding the question that is being asked, not considering alternative explanations for observations or test results, not thoroughly investigating the significance of laboratory findings, or not understanding the power or the limitations of a particular technique. Techniques to recognize and address these errors are the subject of the philosophers of science. Charles Peirce (Buchler, p.190) suggests that the application of logic can serve to help resolve these problems. Karl Popper (Popper) proposes that rigorous experiment can eliminate alternative hypothesis until, in the words of Sherlock Holmes, "Whatever remains must be true." Thomas Kuhn (Kuhn) advises that explanations that make sense, that are pragmatic, are the best explanations. Statisticians have developed statistical approaches for the evaluation of data and subsequent decision making. (Moore, p. 328).

In proceeding towards a resolution of a scientific matter it is of great help to understand the nature of the various cognitive errors that can be made in that process. Various types of cognitive errors have been addressed by philosophers and historians of science, and by practicing scientists. All of the cognitive errors that have been recognized cannot be discussed in this presentation, but some examples follow:

<u>Fallacy of Efficiency</u> (Groopman, p. 99)

An error may result from over-reliance on some efficiently and easily obtainable data.

Following protocols is certainly efficient, as efficient as the protocol allows, but it also limiting. Protocols are by their very nature designed to be applicable to the "typical" case. If the protocol is followed in the atypical case, the results may be efficiently obtained, but the results may be misleading or irrelevant. Kuhn describes this error when discussing the process of proceeding under any specific paradigm: Fact finding under any specific paradigm (a term which Kuhn uses in much the same way as a hypothesis) results in finding facts that are amenable to casual observation or experiment or, in some cases, more "esoteric" data that is obtained from "crafts."(Kuhn, p. 15) Forensic laboratories have many "craftsmen" who generate "esoteric data." Relying on such data may prevent us from discovering explanations outside the operative paradigm.

<u>Genetic fallacy</u> (Fuller, p. 105)

This is the error of determining the validity of an idea based on the origin of the idea. Sometimes this fallacy is accepted based on the personal characteristics of the person offering the idea - I was once accepted as an expert witness solely on the basis of who had trained me in the particular field -- but as scientists we commit the genetic fallacy when we reject an idea based on the technique used to arrive at the idea, or accept uncritically an idea based on its origin.

<u>Fallacy of expectation</u> (Kuhn, p. 36)

When scientists conduct investigations they do so with a common understanding of the assumptions and methods of operations of their science. Kuhn describes this as their paradigm. So when scientists conduct an experiment, they design, conduct, and interpret the experiment within the context of the paradigm under which they work. Since problem solving is often considered a prime challenge for the scientist, Kuhn illustrates the paradigm with the following example. Solving the problem of a jigsaw puzzle is based on a commonly understood paradigm that involved fitting the pieces together by a certain process which results in a complete image, of some type, with no open spaces, and without the use of specials tools. A puzzle solver who randomly arranged the puzzle pieces on a blank piece of paper would not be considered, by traditional jig-saw puzzle solvers, to have solved the puzzle. On the other hand, traditional jig-saw puzzle solvers would consider themselves misled if they were asked to solve a jig-saw puzzle composed of pieces randomly selected from two or more jig-saw puzzles. That is not part of the paradigm.

FORMULATE HYPOTHESES

The conduct of a scientific investigation includes formulation of hypotheses. That this process is not trivial is illustrated by paraphrasing an example from Charles Peirce. (Eco, p. 8) There are two simple logical processes to evaluate certain hypotheses:

Process No. 1 - Deduction

The Rule: We have a jar of blue marbles.

The Case: We select a marble from the jar.

The Result, our hypothesis: The marble will be blue.

We ask the question, "What color is this marble?" We examine the marble, and determine that it is blue, thereby confirming our hypothesis. But we know no more than when we started, given the assumption(a jar of blue marbles) and the nature of the experiment (selecting a marble from the jar). Have we answered any question? Or solved any problem? The deduction is nothing more than a restatement of information already in hand in a different way.

Alternative 2 - Induction

The Case: We have a marble from this jar.

The Result: This marble is blue..

The Rule, our hypothesis: The jar contains blue marbles.

We ask the question, "What color marbles does this jar contain?" We look into the jar to confirm or reject our hypothesis. But can we? Maybe we selected the only blue marble from the jar, which now contains only red marbles. What can we conclude? This is the problem has been posed in a forensic context. (Gaudette)

Alternative 3 – Abduction

This third logical construction has is usually called by a term introduced by Charles Peirce (Misak, p. 18), an "abduction." Peirce is considered one of the four most influential thinkers in the past 150 years of American philosophical inquiry (Menand, p.

ix), and he hit the forensic nail on its head. The same logical process has been called a *presumptive inference*(Eco, p. 69) or *retroduction.(*Buchler, p. 151).

To continue with the same example, the logic of abduction can be illustrated as follows:

The Rule – This is a jar with blue marbles.

The Result – This is a blue marble

The Case, our hypothesis – This marble came from this jar.

Forensic scientists should recognize this logical process as the essence of the operation criminalists refer to as "individualization."

Peirce argues that the processes of deduction and induction are trivial and non-informative. Neither process is capable of providing new information because the conclusions reached in either process are present in the assumptions and observations that are made. Remember the deduction that the marble from the jar of blue marbles is blue, or the inference that the jar of marbles from which the blue marble was drawn will contain blue marbles? Do either of these processes, deduction or induction, provide us with useable information when we are trying to establish an association between one piece of evidence and its source? Certainly they do not, at least not without a lot of other information. Peirce would argue that we are not asking the right question, and therefore are not doing the really relevant experiment. Whether we are talking about jars of marbles, painted cars, or heads of hair, we are not really asking "Could the marble come from this jar?" or "Is the color of the paint the same as the paint on this car?" What we really want to know is "Did the marble come from *this* jar?" or" Did this paint chip come from this car *as a consequence of the event we are investigating?"* Note that the italicized portions of the questions just stated are the relevant parts in the forensic inquiry, and in many ways the essence of what distinguishes the forensic inquiry from the inquiry conducted by other scientists. The determination of the properties of two objects that establish that they could have a common origin is simply a technical operation that precedes a consideration of the questions of concern. This is a “moping up” operation given the hypothesis that the jar has blue marbles. The real questions to be addressed in the forensic science investigation are “Was this evidence produced as a result of the event under investigation?" and "What does this evidence tell us about what happened during the event we are investigating?"

We can recast our problem in terms of trace evidence, and in the logical construction that Peirce calls abduction, in the following way:

The Rule - This garment has red polyester fibers.

The Result - We have some red polyester fibers.

The Case, our hypothesis - These fibers came from this garment (as a result of the incident we are concerned with)?

The Case (or abductive inference) provides a hypothesis for us to test.(Misak. p.18) What is the test? If we design an experiment to negate the null hypothesis (that there is no difference between the red fibers), can we answer affirmatively that the red fibers are from this sweater? Can we design an experiment to negate a hypothesis that the fibers are from some other red acrylic fiber source? What are the criteria to be considered for hypotheses that we will consider? (Misak, p. 103) Do we need a new paradigm to address these questions? How can this conclusion be experimentally verified. What is a meaningful hypothesis to test, or how do we devise a "null hypothesis" to test to encourage our belief in the stated hypothesis. That is precisely the forensic science problem. Not that the jar *has blue marbles* or that the marble *could have come from* the jar, but *Did this marble come from that jar?* And, to make matters even worse, we have to answer the question *Did this marble come from this jar during the incident that we are investigating?*

Formulate alternative hypotheses

Karl Popper is the classical proponent of the alternative hypotheses approach to the "scientific method." Reading books about science written in the period after Popper published, in 1962, *The Structure of Scientific Revolutions* one might conclude that the process of formulating alternative hypotheses and testing them by clever experiments is the final resolution to the validation of any scientific theory or hypothesis. Philosophers of science, both following Popper and preceding him, have argued that there are other considerations in the general approach to science.

Difficulty of formulation of alternative hypotheses

Whether you are a Popperian attempting to formulate an alternative hypothesis to test the validity of some deductive or inductive conclusion, or a follower of the pragmatic approach of Kuhn to formulate a new paradigm that provides for an alternative approach to formation of the hypothesis, there is a variety of constraints that interfere with this process. Cognitive restraints, such as linear thinking (or failing to think "outside of the box"), Ockham's razor (the perceived desirability of the least complicated explanation), or *modal fallacy* (in which, for example, we confuse the terms "could be from" with "is from) (Fuller, p. 105) make the formulation of alternative hypotheses no mean trick.

The process of hypothesis formation is one that requires human creativity. The creativity comes by taking the initial perceptions, and formulating an abductive inference. This is a different process than what is involved in formulating inductive experiments, or making deductive observations, based on initial observations or data.(See discussion in Misak, p. 193)

Evaluation of hypotheses

Mathematics

The necessity of formulating alternative theories to test our hypotheses has resulted in what is currently a popular approach to the problem - a mathematical approach. Peirce had anticipated this approach in his own consideration of the pursuit of scientific inquiry or "truth." Much of his early writing used mathematical examples to illustrate logical processes. (Buchler, p. 187ff) Interestingly, as a young man and protégé of his father, a Harvard professor in the mid 19th Century, Peirce assisted his father in developing statistical data that were used in one of the most famous 19th Century trial – The Howland Will Case. (Menand, p. 163ff). Eventually, however, Peirce dismissed the mathematical approach, saying the mathematics was a tool that was found convenient to use by scientists. Peirce's criticism of the mathematical (and statistical) approach was that the approach required the reduction of the problem to simplify it and to remove any possible ambiguities or uncertainties. The mathematician "frames a pure hypothesis stripped of all features which do not concern the drawing of consequences from it, and this he does without inquiring or caring whether it agrees with the actual facts or not." (Buchler, p. 138) Hence, the process of abduction, the reasoning from the specific observation a specific result or of formulating an alternative hypothesis is the most difficult process in the scientific endeavor.

<u>Alternate reconstruction</u>

We generally rely on two of the principles (Divisible Matter and Exchange) to explain how the evidence came to be present. But neither of these principles relies on the assumption that the presence of the material was the consequence of any specific act. These principles simply state that when certain phenomena occur (contact between two objects, or the application of a force sufficient to cause failure in some object), certain results will be present that can be observed in either transfer of material or alteration of some physical object. So we must consider, devise experimental ways to reproduce, and measure the consequences of actions and interactions that could have produced the evidence. In other words, we must test various reconstructions to see if they produce the evidence that was found. And then we must consider the certainty with which the evidence produced by those actions would have been found. We generally cannot go back and look for that evidence after we have done the experiment. This places a rather daunting burden on the evidence recognition and preservation operations at the crime scene and illustrates the intimate connection between the crime scene and the proof of the hypothesis developed *after* the examination of the evidence has been completed. It is apparent that the crime scene processing is more, much more, than simply documenting and picking up the objects that are apparently related to some initial theory or reconstruction of the event.

Conclusions

Can the application of the principles and use of the unit operations of criminalistics inform decision-makers in the justice system to allow them to make better decisions about matters that come before them? I believe they can.

The crime scene is a puzzle. The pieces of the puzzle are physical objects at the crime scene. However, the jigsaw puzzle paradigm is not applicable to the crime scene: We cannot assume that all of the pieces of our puzzle are present, and we cannot assume that all of the pieces present are part of the puzzle. Some common tools, such as a knife or a saw, are inappropriate for solving a jigsaw puzzle, and some tools may not be appropriate for solving the crime scene puzzle. The solution of the jigsaw puzzle we can recognize as correct because it forms a coherent image with no gaps. The same expectation for the solution to the crime scene puzzle is not expected. The jigsaw has only one solution that fellow jigsaw puzzle solvers would agree is correct. On the other hand, there may be alternative solutions to the crime scene puzzle that are acceptable.

We need to develop the crime scene, or event, solving paradigm, and present a convincing argument that our paradigm has something of value to offer to the judicial system. We don't need to accept someone else's prescription for "validation" techniques - we should validate the techniques we use and convince others that these techniques offer some value. We have to be forthright about their limitations, but not be timid in offering our opinions.

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